The Urgency of Energy Efficiency

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DECAY MODES OF SPIN-TWO MESONS*

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Recent evidence indicates the existence of a nonet of $J^P = 2^+$ mesons. These are

$K^*(1430)$: $T = \frac{1}{2}, Y = \pm 1$,

$A_2(1320)$: $T = 1, Y = 0$,

$f(1250)$: $T = 0, Y = 0$,

$f'(1525)$: $T = 0, Y = 0$.

that

$$f' \approx \tfrac{1}{2}\sqrt{3} f_8 - \tfrac{1}{2} f_1,$$

$$f \approx \tfrac{1}{2} f_8 + \tfrac{1}{2}\sqrt{3} f_1.$$

Consider the decays of the $J^P = 2^+$ mesons into two pseudoscalar mesons. We assume that the coupling constants are given by exact SU(3), so that there are only two relevant couplings

Present at Art's Conversion

Efficient Use of Energy

(The APS Studies on the Technical Aspects
of the More Efficient Use of Energy)

1974

PARTICIPANTS AND BRIEFERS

Part I A Physics Perspective

Participants:

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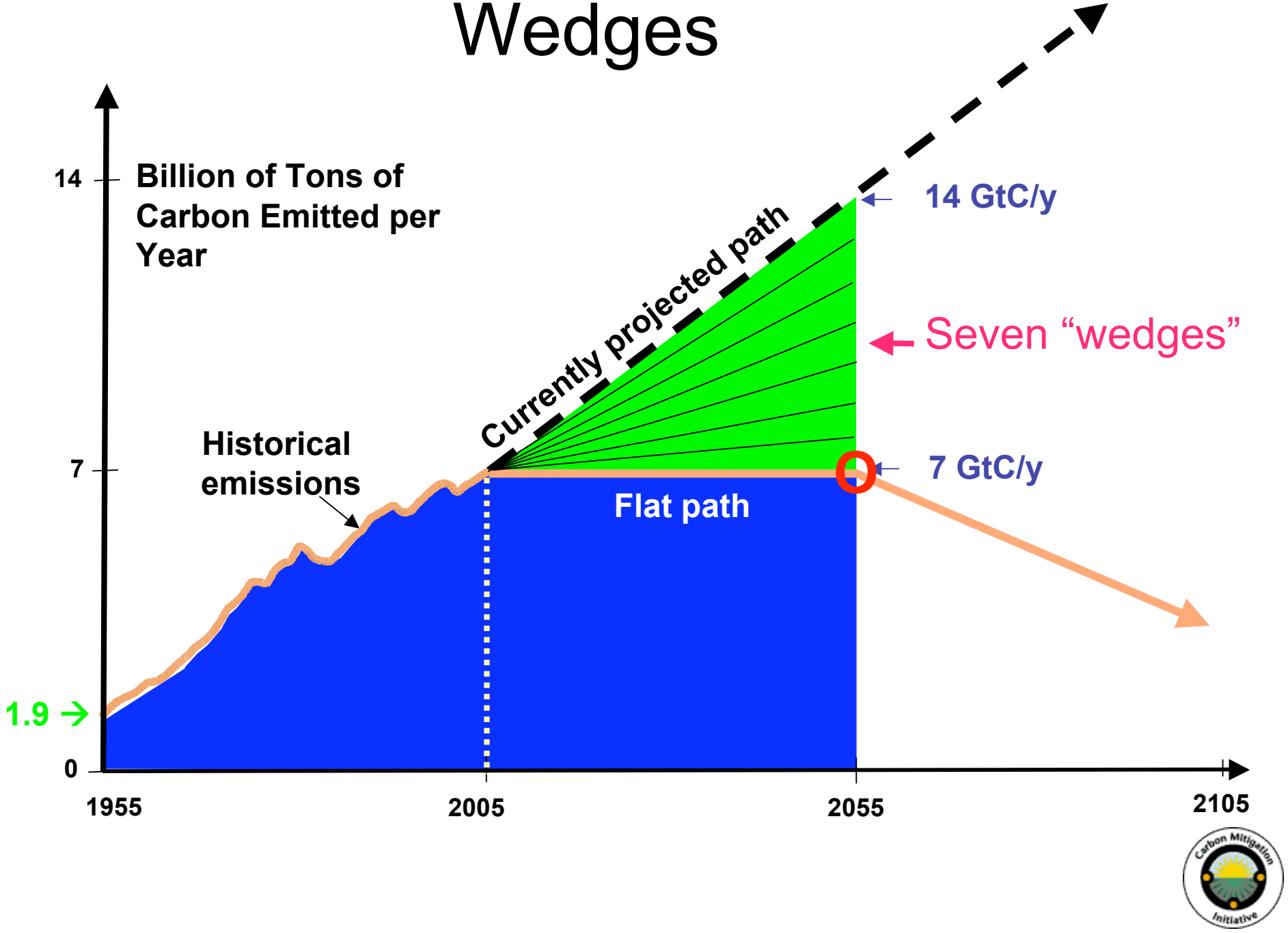
Real men don't do efficiency

Although the book about quiche hadn't been written yet, a strong message in [the early 1970s] was that real men don't study how to use less energy.

We physicist who worked together on the 1974 American Physical Society summer study [were seeking to undermine the belief] that it is appropriate for physicists to work on problems of energy supply, but inappropriate for us to work on problems of energy use. …Our counterexamples would be ourselves.

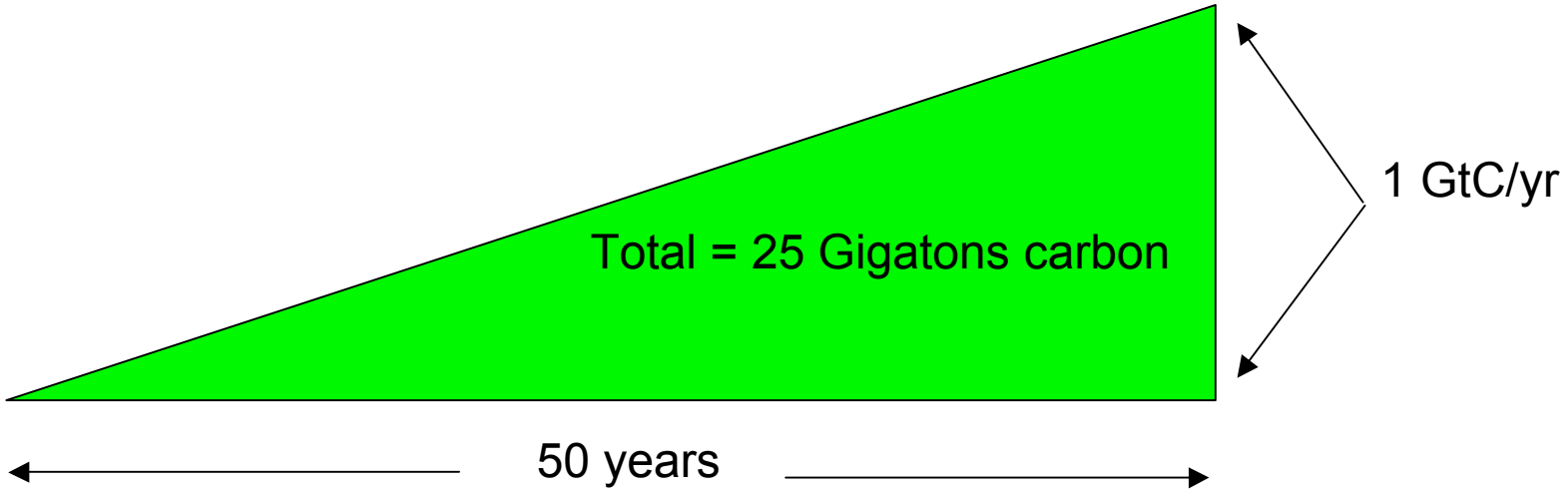
Robert Socolow, "Reflections on the 1974 APS energy study," *Physics Today*, January 1986, pp. 2-6

Wedges


14
Billion of Tons of Carbon Emitted per Year
7
1.9
0
1955
2005
2055
2105
Historical emissions
Currently projected path
14 GtC/y
Seven "wedges"
7 GtC/y
Flat path

What is a “Wedge”?

A “wedge” is a strategy to reduce carbon emissions that grows in 50 years from zero to 1.0 GtC/yr. The strategy has already been commercialized at scale somewhere.



Cumulatively, a wedge redirects the flow of 25 GtC in its first 50 years. This is 2.5 trillion dollars at $100/tC.

A “solution” to the CO_2 problem should provide at least one wedge.

Efficient Use of Electricity

motors

lighting

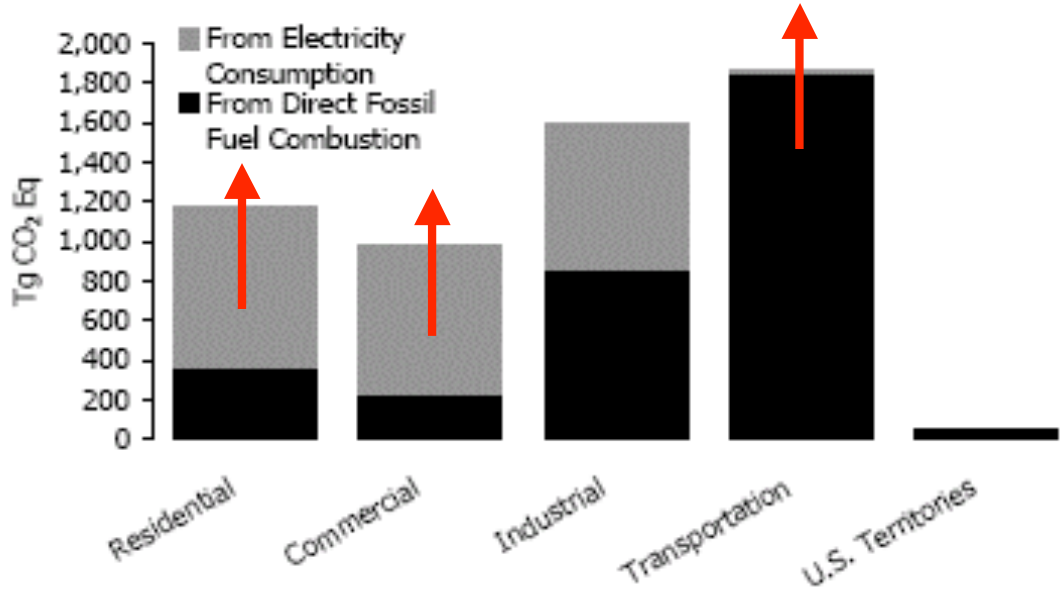
cogeneration

Effort needed by 2055 for 1 wedge:

.

25% reduction in expected 2055 electricity use in commercial and residential buildings

At the power plant, CO_2 heads for the sky, the electrons head for buildings!



1) Electricity in buildings, and 2) all forms of transport are the components of CO_2 emissions that rise in a post-industrial society.

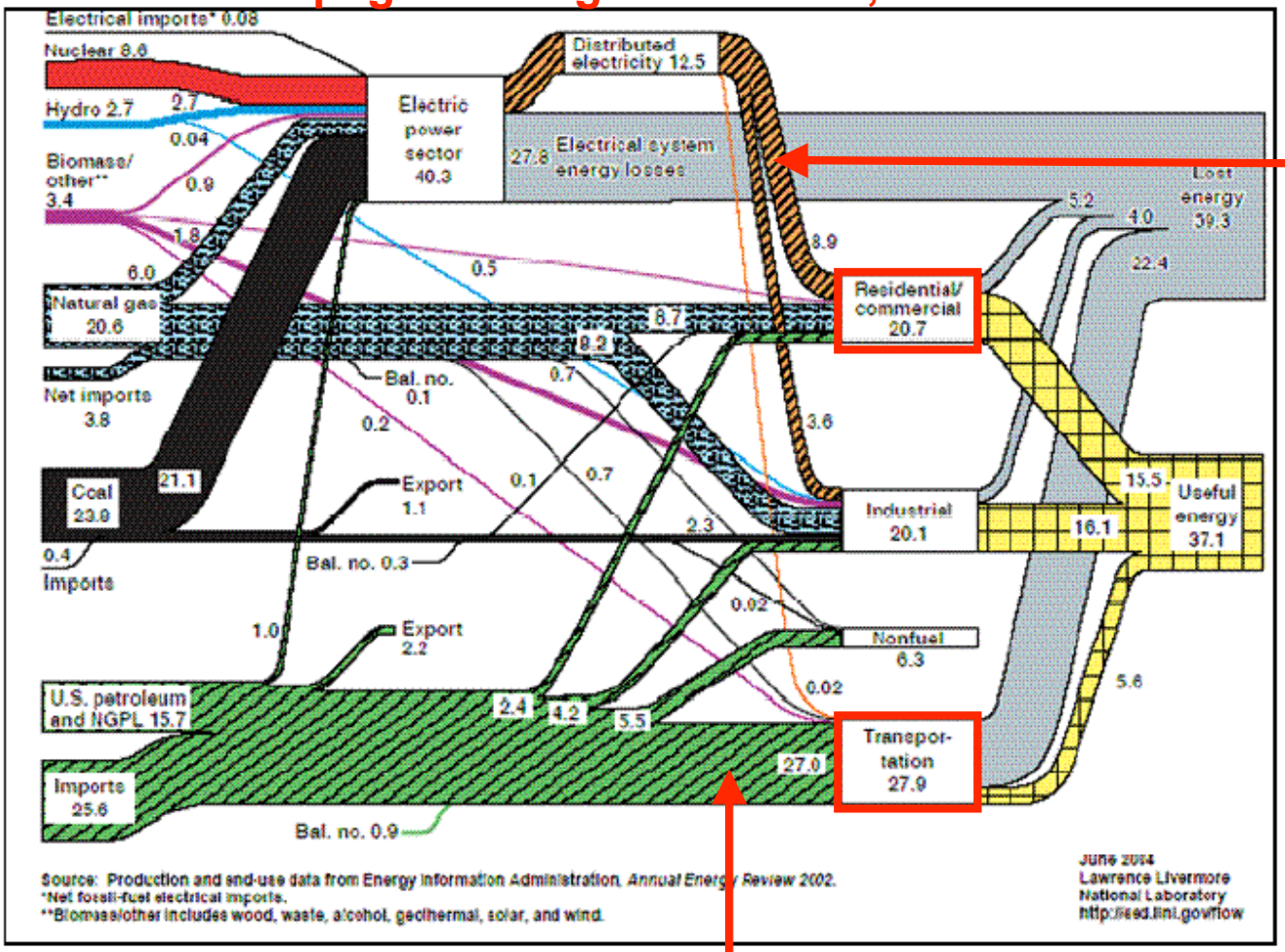
They are the two top places to look for wedges.

Figure 2-9: 2004 End-Use Sector Emissions of CO_2 from Fossil Fuel Combustion

Source: U.S. EPA

A power plant is a building!

Spaghetti diagram for U.S., 2002

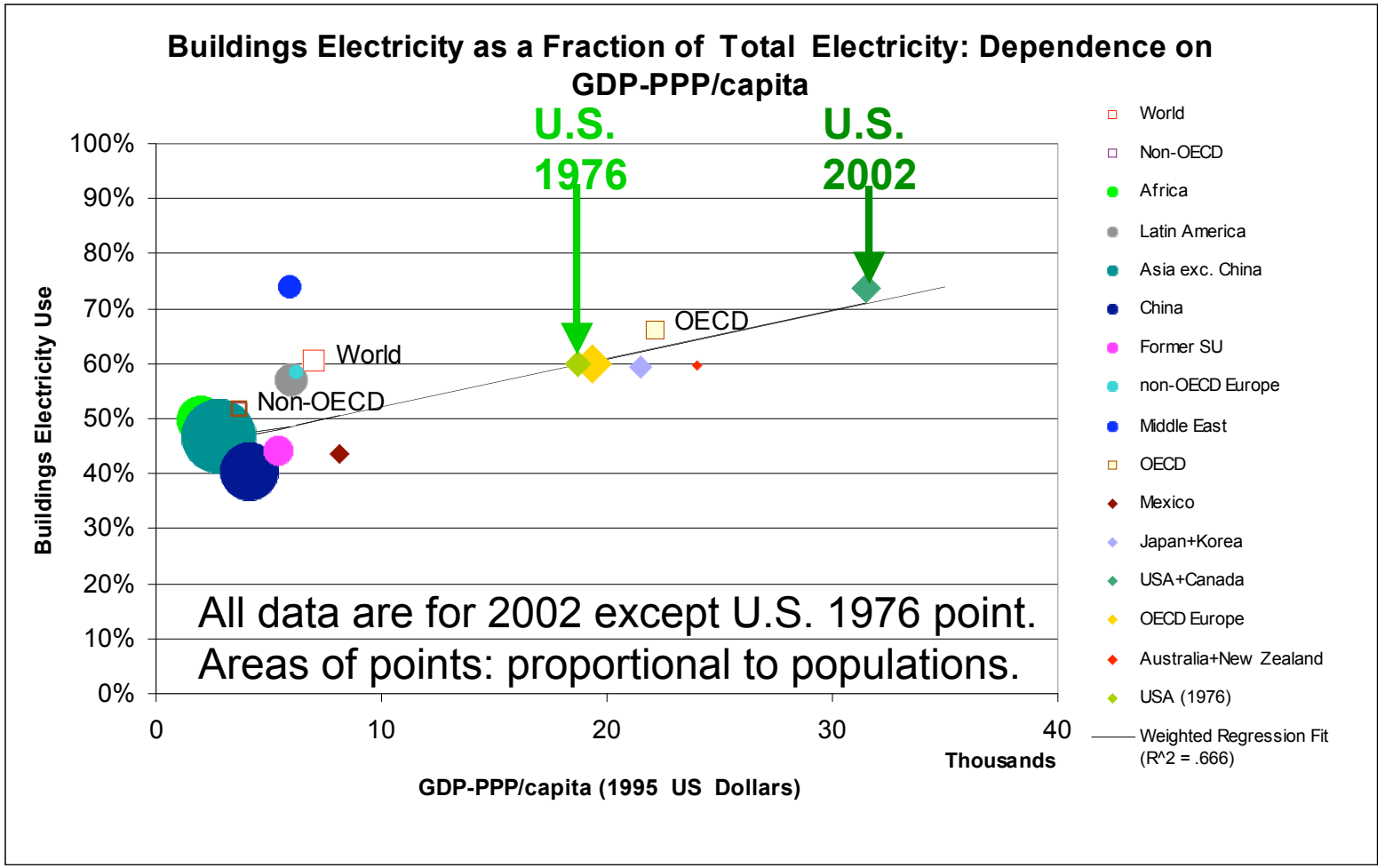


71% of electricity goes to buildings (60% in 1976)

Buildings elec is fastest growing element, 1976-2002: Multiple is 2.1

67% of oil used in U.S. goes to vehicles (54% in 1976)

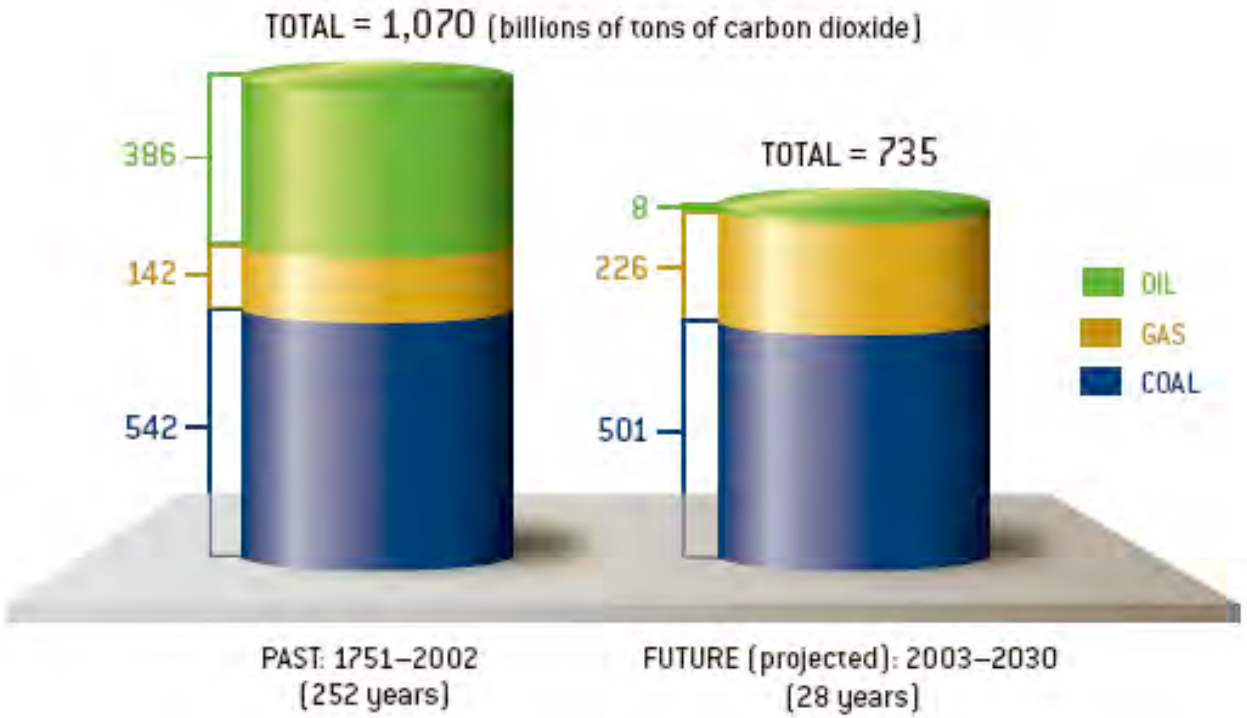
A larger fraction of electricity goes to buildings in rich countries



"Buildings Electricity" = 100% Commercial and Residential + 15% Industrial + 10% Agricultural.

Data provided by Paul Waide, graphics by Shoibal Chakravarty

The Demography of Capital



Historic emissions, all uses

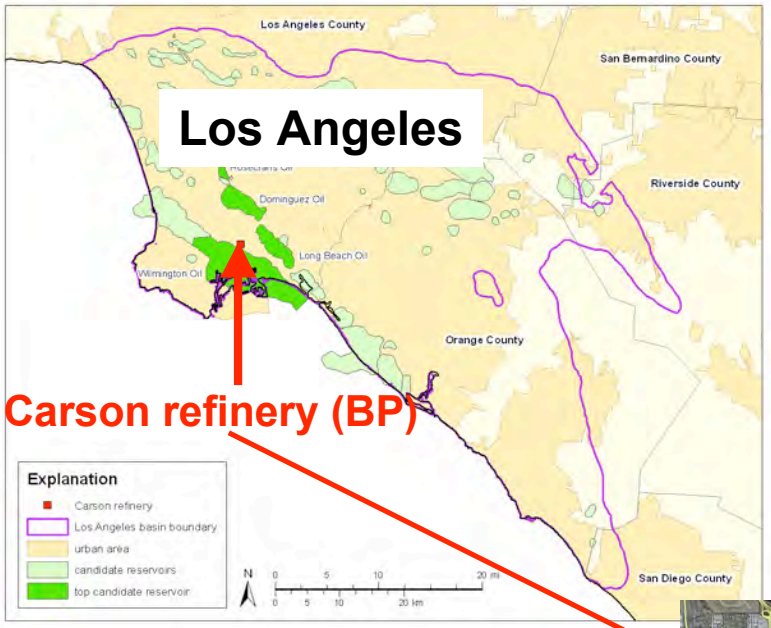
2003-2030 power-plant lifetime CO_2 commitments
WEO-2004 Reference Scenario.
Lifetime in years: coal 60, gas 40, oil 20.

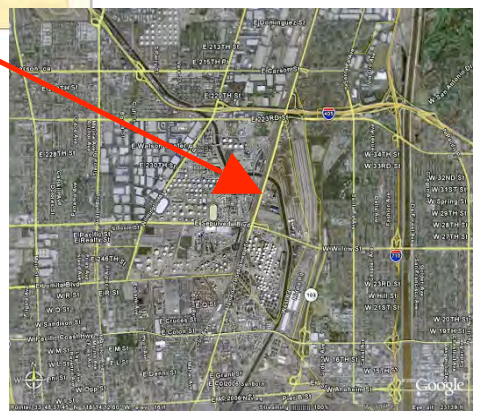
Policy priority: Deter investments in new long-lived high-carbon stock: not only new power plants, but also new buildings.

Needed: "Commitment accounting."

Credit for comparison: David Hawkins, NRDC

Hydrogen Power from Refinery Residues in California





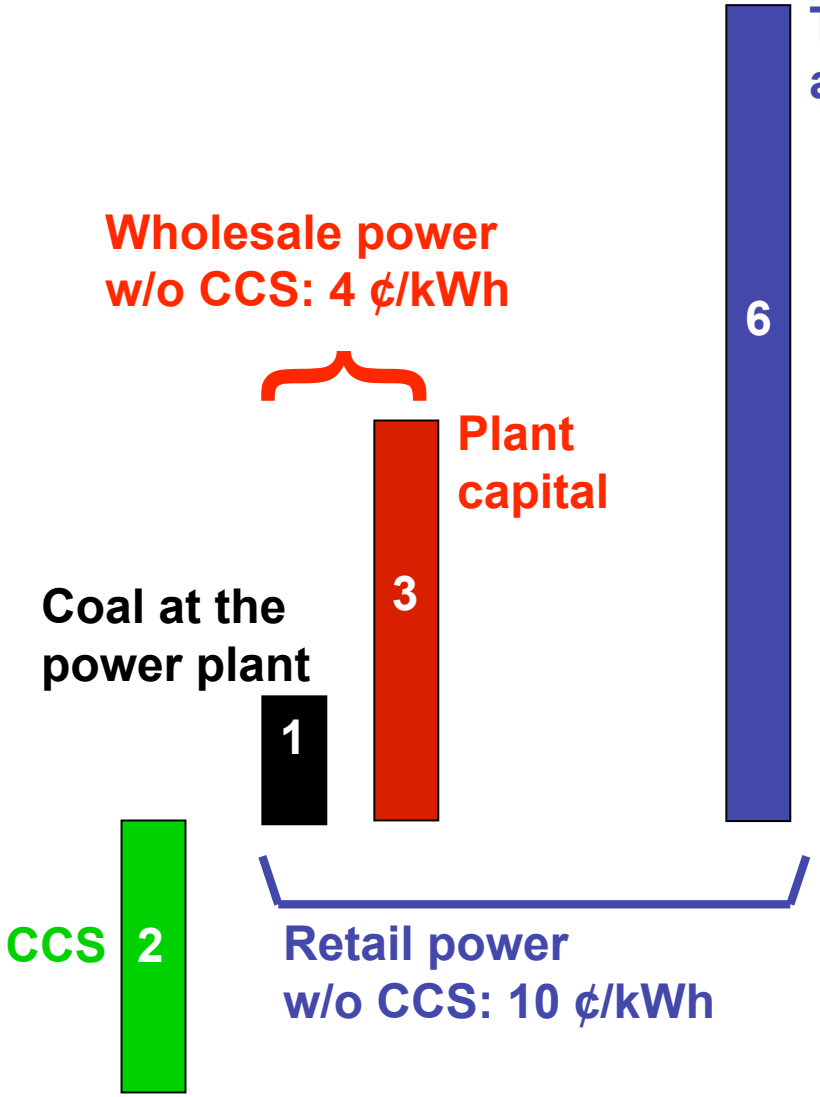
BP will:

gasify 4500 t/day of petcoke, producing H_2 and CO_2, at its 260,000 bbl/day Carson refinery

burn 800 tons/day of H_2 in turbines for 510 MW of power

export off-site 4 $MtCO_2$/yr for enhanced oil recovery.

$100/tC ≈ 2¢/kWh induces CCS. Three views.



A coal-gasification power plant can capture CO_2 for an added 2¢/kWh ($100/tC). This:

triples the price of delivered coal;

adds 50% to the busbar price of electricity from coal;

adds 20% to the household price of electricity from coal.

Efficient Use of Fuel

Effort needed by 2055 for 1 wedge:

2 billion cars driven 10,000 miles/yr at 60 mpg instead of 30 mpg.

1 billion cars driven, at 30 mpg, 5,000 instead of 10,000 miles/yr.

CCTP (U.S.) draft, Sept. 2005: 1 billion cars driven 10,000 miles/yr at 40 mpg instead of 20 mpg

A car at 30 mpg, 10,000 miles/yr, emits 1 tC/yr.

*Coal-based Synfuels with CCS**

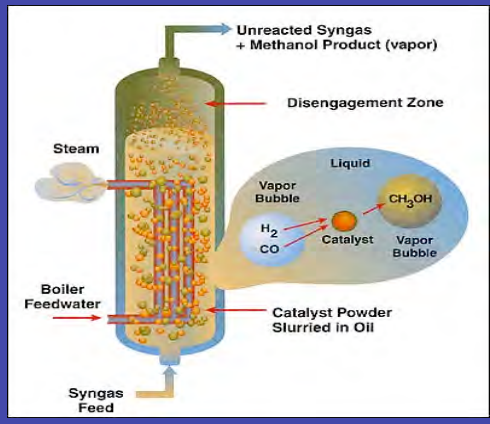
Carbon capture and storage

Effort needed for 1 wedge by 2055

Capture and storage of the CO_2 byproduct at plants producing 30 million barrels per day (mbd) of coal-based synfuels. (Global oil: 80 mbd; South Africa synfuels, 0.16 mbd.)

Assumption: half of C originally in the coal is available for capture, half goes into synfuels.

120 Mt/yr coal yields 1 mbd synfuels.
Consumption (Mt/yr, 2002): World, 4800; China, 1300; U.S and Canada ,1100.



Liquid-phase synthesis of methanol from CO + H_2. Graphics courtesy of DOE Office of Fossil Energy

Result: Coal-based synfuels have no worse CO_2 emissions than petroleum fuels, instead of doubled emissions.

How soon can CO_2 capture and storage be required at all new coal plants?

- A key goal of climate change policy should be to enable the arrival, at the earliest reasonable date, of a time after which *all* new coal plants, for both power and fuels, are built with CCS.

- During the transition period, every new coal policy and every new coal plant should contribute to the learning required to achieve this goal.

- The first N plants should be subsidized. What is N?

  N may be 10, or even 20: a) many kinds of coal, b) capture concepts other than gasification, c) many kinds of reservoirs

- Coal must also become more clean "upstream."

California "pull" is invaluable!

Examples of targeted R&D on components and systems

1. CO_2 Capture and Storage

a. Capture: gas separation at high pressure

b. Storage: efficient displacement of one fluid by another in porous media

2. Reinventing the building

a. Components: windows, lighting, appliances (LBNL success stories, globally recognized)

b. Thermal integration: envelope, heating, cooling, hot water, incident sunlight, wind, subsurface

c. Electricity integration: appliances, incident solar photons, local wind, grid exchange)

3. Reinventing personal transport

a. Integration the electricity grid and the vehicle

b. Hydrogen safety

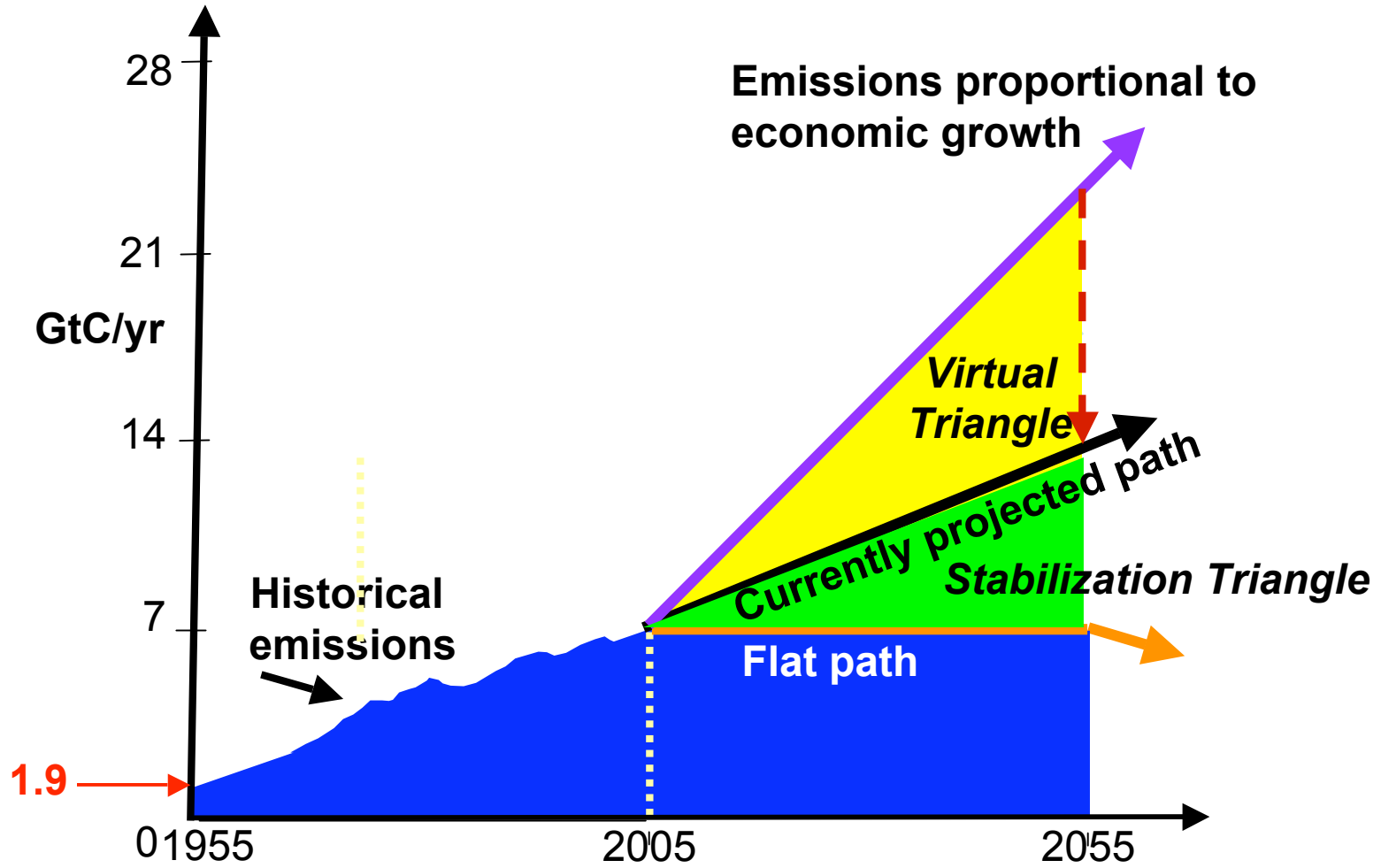
c. Teleconferencing and the trip not taken

4. Renewables

a. Ecologically smart large-scale biomass

b. Ethically astute “Earth engineering”

The Virtual Triangle: Large Carbon Savings Are Already in the Baseline



Models differ widely in their estimates of contributions to the virtual triangle from structural shifts (toward services), energy efficiency, and carbon-free energy.

Do wedge strategies get used up?

For any strategy, is the second wedge easier or harder to achieve than the first? Are the first million two-megawatt wind turbines more expensive or cheaper than the second million two-megawatt wind turbines?

> The first million will be built at the more favorable sites.
>
> But the second million will benefit from the learning acquired building the first million.

The question generalizes to almost all the wedge strategies: Geological storage capacity for CO_2, land for biomass, river valleys for hydropower, uranium ore for nuclear power, semiconductor materials for photovoltaic collectors.

All present the same question: ***Will saturation or learning dominate?***

Answer: Wherever Art's influence is felt, learning!

Prospicience

Prospicience: “The art [and science] of looking ahead.” We need a new word to describe a new intellectual domain.

In the past 50 years we have become aware of our deep history: the history of our Universe, our Earth, and life. All this is quantitative for the first time.

Can we achieve a comparable quantitative understanding of human civilization at various future times: 50 years ahead *vs.* 500 *vs.* 5000 *vs.* longer?

Imagine spending as much effort on our collective destiny on Earth as we spend on our personal destiny in the afterlife!

A world transformed by deliberate attention to carbon

A world with the same total CO_2 emissions in 2055 as in 2005 will also have:

1. Institutions for carbon management that reliably communicate the price of carbon.
2. If wedges of *nuclear power* are achieved, strong international enforcement mechanisms to control nuclear proliferation.
3. If wedges of *CO2 capture and storage* are achieved, widespread permitting of geological storage.
4. If wedges of *renewable energy* and *enhanced storage in forests and soils* are achieved, extensive land reclamation and rural development.
5. **A planetary consciousness**.

Not an unhappy prospect!

Robert Frost
Two Tramps in Mud Time
(opening stanza)

Out of the mud two strangers came
And caught me splitting wood in the yard.
And one of them put me off my aim
By hailing cheerily "Hit them hard!"
I knew pretty well why he dropped behind
And let the other go on a way.
I knew pretty well what he had in mind:
He wanted to take my job for pay.

Robert Frost

Two Tramps in Mud Time

(penultimate stanza)

Nothing on either side was said.
They knew they had but to stay their stay
And all their logic would fill my head:
As that I had no right to play
With what was another man's work for gain.
My right might be love but theirs was need.
And where the two exist in twain
Theirs was the better right -- agreed.

Robert Frost

Two Tramps in Mud Time

(final stanza)

But yield who will to their separation,
My object in living is to unite
My avocation and my vocation
As my two eyes make one in sight.
Only where love and need are one,
And the work is play for mortal stakes,
Is the deed ever really done
For Heaven and the future's sakes.